THE EXTENSION OF THE SOLAR SYSTEM BEYOND NEPTUNE, AND THE CONNECTION EXISTING BETWEEN PLANETS AND COMETS.

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One of the most remarkable results of the writer's recent researches on the origin of the solar system has consisted in the development of a satisfactory proof that the primordial nuclei of the planets were formed at great distances from the sun, and that their primitive orbits were highly eccentric like those now described by the comets; so that in the last analysis it is shown that the two classes of bodies are merged together, or rather that the planets have been built up by the agglomeration of cosmical dust, in the form of comets, and other fragments of matter, from our ancient nebula. The following is a brief outline of the thread of argument leading to this conclusion:

1. It is shown by the exact data supplied by Babinet's criterion that not one of our planets could have been thrown off from the sun, by acceleration of rotation, as imagined by Laplace in 1796, but that the nuclei must have started in the distance and since neared the sun, by insensible degrees, as the masses were gradually augmented by precipitations from the surrounding nebular medium.

2. When it was thus demonstrated by exact calculation that the premise handed down by Laplace is erroneous, our theory of planetary genesis was placed on a new basis by the proof that the roundness of planetary orbits is due to the secular action of a resisting medium, which has reduced the size of the planetary orbits and rendered them almost exactly circular.

3. In order to be so exactly circular, as they are now found to be, these orbits must originally have been very large, and also highly eccentric, like the orbits of comets; the orbits accordingly have been reduced in size by encounters with the other minor bodies, the

absorption of which also increased the masses of the planets enormously.

4. If one asks for ocular evidence that the planetary bodies have been in collision with smaller masses, this evidence is found in the phenomena shown in the face of the moon, which was formerly an independent planet, and is so small a globe as never to have developed water or atmosphere; so that it is a kind of hermetically sealed celestial museum, so near us in space that it serves for the illustration of the process of *absorption* and *capture* in cosmogony. The type of collisions visibly illustrated by the dents in the moon's face necessarily have occurred with all the planets; but the moon as our nearest planetary neighbor alone enables us to study the process of accretion by collisions with bodies of all sizes, from particles to satellites as large as twenty miles in diameter.

5. The obvious deposits of dust over the older lunar craters give them an aspect of great age, and in many cases the outlines of the craters are practically obliterated. In other cases newer craters are formed over the older ones; so that we can certainly infer by direct observation that the moon has been built up by accretion, dust being gathered in to be deposited over dust, and crater over crater. This is the same process which we see at work on the earth, except that the meteorites now swept up by our planet are generally small and consumed in the air before reaching the earth.

6. Since the planets were begun as independent nuclei in our nebula, and since augmented by the gathering together of an infinite number of small bodies, such as comets, the matter of planets and comets must necessarily be the same, for they are common products of our ancient nebula. The planets have been built up by the gathering in of satellites, comets and smaller particles of cosmical dust.

7. Now we have pointed out that Neptune's orbit is too round for it to be the outermost of the planets of the solar system. If the resisting medium was dense enough at that great distance to produce such extreme circularity in the motion of Neptune, there was enough of the nebulosity beyond that planet to make several more planets of comparatively large size. Thus it is certain that our system does not terminate at Neptune, but extends on almost indefinitely. It is probable that in time we may be able to discover

several trans-Neptunian planets; but the recognition of these remote bodies will be difficult, owing to their slow motion and the faintness of the sun's light at that great distance.

8. The notable expansion of our ideas of what constitutes a nebula will thus be of great practical use in the progress of astronomy. The overthrow of the theory of Laplace is only a small part of the service to science brought about by the discovery of the true laws of the development of our system. As the *comets* recede to distances amounting to thousands of times the earth's distance from the sun, so also must embryo *planets* be imagined to bridge over the gap heretofore separating the planets and comets. And we may imagine planets to extend to at least 100, perhaps 1,000 times the earth's distance from the sun. Some of the comets may go 100 times further yet, but at such great distances we can never know much about their motions in these remote regions of space.

9. When we contemplate the vast extent of our primordial nebula implied in the distances to which the comets recede, and remember the large apparent areas covered by many other nebulæ in the sky, we see that our solar nebula evidently was of the ordinary type, and that it certainly was not a gaseous mass in equilibrium under hydrostatic pressure and extending only to the orbit of Neptune. Of course all these old doctrines of Laplace are now quite abandoned, but they long deceived us, and kept cosmogony in a stationary condition for over a century.

10. The origin of the primordial nuclei in the distance is a necessary consequence of the working of planetary bodies towards the dominant center of attraction—the sun. Hence the formation of a system of planets is necessarily from without inward, just the reverse of the traditions handed down by Laplace. This harmonizes perfectly with the new theory of the spiral nebulæ, which makes the ring nebulæ particular cases of the more general spiral tendency. The formation in all cases is from the outside towards the center. Planets form in all nebulæ, and since small bodies approach the center more rapidly than large ones, under the action of a resisting medium, it follows that the planets thus capture systems of satellites such as we observe attending the planets of the solar system.

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